Physics Exam
University of Houston Math Contest 2024

Unless otherwise specified, please use g as the acceleration due to gravity at the surface of the Earth. Vectors $\hat{\boldsymbol{x}}$, $\hat{\boldsymbol{y}}$, and $\hat{\boldsymbol{z}}$ are unit vectors along x, y, and z, respectively, in a normal Cartesian coordinate system. Let G be the universal gravitational constant. To simplify calculations, use $g = 10\ m/s^2$, and use the value of the trigonometric functions at the following angles:

θ	0°	30°	45°	60°	90°
$\sin\theta$	0	$\frac{1}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{\sqrt{3}}{2}$	1
$\cos\theta$	1	$\frac{\sqrt{3}}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{2}$	0
$\tan\theta$	0	$\frac{1}{\sqrt{3}}$	1	$\sqrt{3}$	Not defined

Q-01) Consider a truck that travels between Houston and Dallas. Which of the following statements is true (choose only one)?
A. The truck's average speed can be less than the magnitude of its average velocity.
B. The magnitude of the truck's average velocity can never be equal to its average speed.
C. The truck's average speed can never be greater than the magnitude of its average velocity.
D. The magnitude of the truck's average velocity can be negative.
E. The truck's average speed can be negative.
F. None of the above

Q-02) A drag racer starts from rest and accelerates uniformly at 4.00 m/s^2 in a straight line for 10.0 sec. Then it decelerates at a constant rate of 2.00 m/s^2 until the drag racer stops. Find the average velocity of the drag racer during the trip.
A. 10 m/s
B. 20 m/s
C. 30 m/s
D. 40 m/s
E. 50 m/s
F. None of the above

Q-03) A ball is thrown straight up from ground level next to a tall building. The time that elapses from when the ball passes the floor of the third floor of the building on the way up, to when it passes the ceiling of the fifth floor on the way up, it is 1.00 s. Every floor in the building is 3.00 m high. What is the ball's initial speed?
A. $\sqrt{86}$ m/s
B. $\sqrt{103}$ m/s
C. $\sqrt{136}$ m/s
D. $\sqrt{263}$ m/s
E. $\sqrt{316}$ m/s
F. None of the above

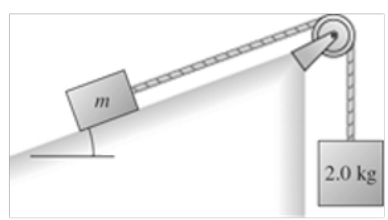
Q-04) A person is in an elevator that is moving at a constant speed. Suddenly, the elevator's speed changes, causing the person to feel an apparent increase in his weight. What could explain this change in the person's apparent weight? Choose the most complete answer.
A. The elevator is moving up, and the speed is decreasing
B. The elevator is moving up, and the speed is increasing
C. The elevator is moving down, and the speed is decreasing
D. The elevator is moving down, and the speed is increasing
E. More than one of the above is correct
F. None of the above

Q-05) An athlete throws a ball toward a wall at a speed of $\sqrt{120}$ m/s and an angle of $60°$ above the horizontal. The wall is at a horizontal distance of $\sqrt{12}$ m from the realized point of the ball. How high above the release point does the ball hit the wall?
A. 1.00 m
B. 2.00 m
C. 3.00 m
D. 4.00 m
E. 5.00 m
F. None of the above

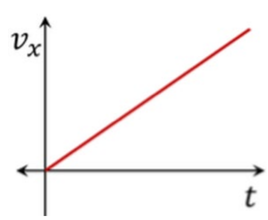
Q-06) A ball thrown horizontally from a point 20 m above the ground strikes the ground after traveling horizontally at a distance of 30 m. With what speed was it thrown?
A. 5 m/s
B. 10 m/s
C. 15 m/s
D. 20 m/s
E. 25 m/s
F. None of the above

Q-07) A boat crosses a river by swimming perpendicular to the water current at a speed of 0.5 m/s relative to the water. The river is $\sqrt{27}$ m wide, and the boat reaches the opposite side at a distance $\sqrt{9}$ m downstream from its starting point. How fast is the water flowing with respect to the ground?
A. $1/\sqrt{2}$ m/s
B. $1/\sqrt{3}$ m/s
C. $1/\sqrt{6}$ m/s
D. $1/\sqrt{8}$ m/s
E. $1/\sqrt{12}$ m/s
F. None of the above

Q-08) The figure shows a block of mass m = 3 kg resting on a $30°$ slope. The static and kinetic friction coefficients between the block m and the slope's surface are 0.500 and 0.400, respectively. It is connected using a very light string over an ideal pulley to a hanging block of mass M = 2.00 kg. The string above the slope pulls parallel to the surface. Find the magnitude of the force of friction between the block m and the slope.
A. 5 N
B. 20 N
C. $(6\sqrt{3})$ N
D. $(15\sqrt{3})/2$ N
E. $(15\sqrt{3})$ N
F. None of the above



Q-09) A net force, $\mathbf{F}_{net}$, acts on an object of mass m in the positive x direction, and the velocity vs. time graph of the object's motion is shown in the figure. If m had been smaller while $\mathbf{F}_{net}$ remained the same, how would the graph be expected to change?
A. Changing the mass would not affect the graph.
B. The slope of the graph would change to a zero slope, a horizontal line.
C. The slope would remain the same, but the graph would shift downward.
D. The slope of the graph would decrease and remain positive and constant.
E. The slope of the graph would increase and remain positive and constant.
F. None of the above



Q-10) A physicist is doing experiments sliding a 4.00 kg box into an incline. He changes the inclined angle and finds that the minimum angle for the box to slide is 60 degrees. Once the box moves, it will accelerate at $\sqrt{3}$ m/s^2. Find his coefficients of static friction between the box and the incline.

A. $1\sqrt{3}/5$
B. $2\sqrt{3}/5$
C. $3\sqrt{3}/5$
D. $4\sqrt{3}/5$
E. $5\sqrt{3}/5$
F. None of the above

Q-11) A physicist is doing experiments sliding a 4.00 kg box into an incline. He changes the inclined angle and finds that the minimum angle for the box to slide is 60 degrees. Once the box moves, it will accelerate at $\sqrt{3}$ m/s^2. Find his coefficients of kinetic friction between the box and the incline.

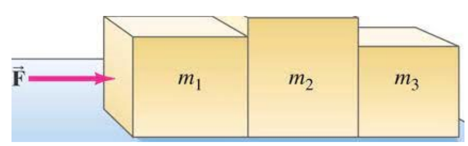
A. $1\sqrt{3}/5$
B. $2\sqrt{3}/5$
C. $3\sqrt{3}/5$
D. $4\sqrt{3}/5$
E. $5\sqrt{3}/5$
F. None of the above

Q-12) A 4.00 kg toy car moves along a straight line at constant acceleration. After it moves 20.0 m, its velocity increases from an initial value of 4.00 m/s to 6.00 m/s. Find the magnitude of the net force acting on the object.

A. 1.00 N
B. 1.50 N
C. 2.00 N
D. 2.50 N
E. 3.00 N
F. None of the above

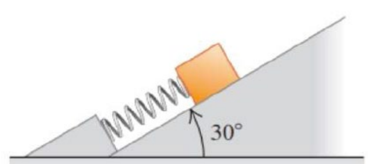
Q-13) Three blocks, m_1=3.00 kg, m_2=2.00 kg, and m_3=4.00 kg, are pushed across a frictionless floor by horizontal force F=10 N, as shown in the figure. Find the ratio F_{23} / F_{12}, where F_{12} is the magnitude of the contact force between m_1 and m_2, and F_{23} is the contact force between m_2 and m_3.

A. 3/4 N
B. 9/4 N
C. 4/9 N
D. 4/5 N
E. 1 N
F. None of the above



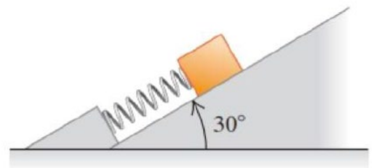
Q-14) A 20.0 kg block is pushed again a spring along an inclined surface, as shown in the figure. The surface makes a 30-degree angle with respect to the horizontal. The spring, with a spring constant of 2500 N/m, is compressed 10.0 cm from its equilibrium. Find the acceleration of the block at the moment it is released.

A. 5.00 m/s^2
B. 7.00 m/s^2
C. 7.50 m/s^2
D. 12.5 m/s^2
E. 12.0 m/s^2
F. None of the above



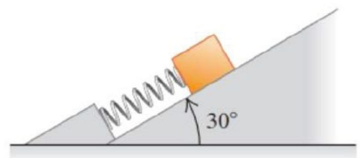
Q-15) A 20.0 kg block is pushed again a spring along an inclined surface, as shown in the figure. The surface makes a 30-degree angle with respect to the horizontal. The spring, with a spring constant of 2500 N/m, is compressed 10.0 cm from its equilibrium. Find the distance from the released position to where the block reaches its maximum speed.

A. 20.0 mm
B. 40.0 mm
C. 60.0 mm
D. 80.0 mm
E. 100 mm
F. None of the above



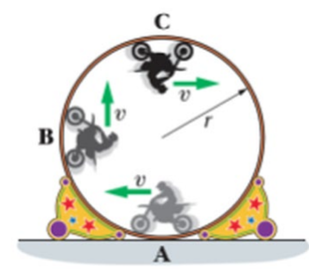
Q-16) A 20.0 kg block is pushed again a spring along an inclined surface, as shown in the figure. The surface makes a 30-degree angle with respect to the horizontal. The spring, with a spring constant of 2500 N/m, is compressed 10.0 cm from its equilibrium. Find the distance from the released position to where the block reaches its maximum height.

A. 110 mm
B. 115 mm
C. 120 mm
D. 125 mm
E. 130 mm
F. None of the above



Q-17) A person drives a motorcycle with a constant speed v around the inside of a vertical track with a radius r, as shown in the figure. The combined mass of the motorcycle and the person is m. The motorcycle did not lose contact with the track, so its normal force did not vanish. Which of the following expressions describes the normal force exerted by the track on the motorcycle when it is at position C?

A. $m\frac{v^2}{r}$
B. $\left(m\frac{v^2}{r} + mg\right)$
C. $\left(m\frac{v^2}{r} - mg\right)$
D. $\left(\frac{v^2}{r} + mg\right)$
E. $\left(\frac{v^2}{r} - mg\right)$
F. None of the above



Q-18) A 50 g puck is moving in a circle on a horizontal frictionless surface. It is held in its path by a massless string 0.20 m in length. The puck makes 150 revolutions every minute. What is the magnitude of the tension in the string?

A. $2\pi^2$
B. π^2
C. $\frac{1}{2}\pi^2$
D. $\frac{1}{3}\pi^2$
E. $\frac{1}{4}\pi^2$
F. None of the above

Q-19) The center of planet A is a distance D from the center of planet B. The mass of planet B is three times the mass of planet A. At some distance x from the center of planet A, along a line connecting the centers of the planets, the net force on an object with mass M will be zero. Find the distance x from the center of planet A, where the gravitational force is zero.

A. $\frac{1}{(\sqrt{3}+1)}$D
B. $\frac{\sqrt{3}}{(\sqrt{3}+1)}$D
C. $\frac{1}{(\sqrt{3}-1)}$D
D. $\frac{\sqrt{3}}{(\sqrt{3}-1)}$ D
E. $\frac{1}{(\sqrt{3})}$D
F. None of the above

Q-20) A hypothetical planet has a mass of one-half that of the Earth and a radius of twice that of the Earth. What is the acceleration due to gravity on the planet in terms of *g*, the acceleration due to gravity at the surface of the Earth?

A. $4g$
B. $2g$
C. $\frac{1}{2}g$
D. $\frac{1}{4}g$
E. $\frac{1}{8}g$
F. None of the above

Q-21) Four masses m are positioned at the corners of a square side r. Find the magnitude of the net force acting on one of the masses due to the other three.

A. $\left(\frac{3}{\sqrt{2}}\right)\frac{Gm^2}{r^2}$
B. $\left(2+\frac{1}{\sqrt{2}}\right)\frac{Gm^2}{r^2}$
C. $\left(\sqrt{2}+\frac{1}{\sqrt{2}}\right)\frac{Gm^2}{r^2}$
D. $\left(\sqrt{2}\right)\frac{Gm^2}{r^2}$
E. $\left(1+\frac{3}{\sqrt{2}}\right)\frac{Gm^2}{r^2}$
F. None of the above

Q-22) A satellite of mass M takes time T to orbit the Earth. If the satellite had twice as much mass, the time for it to orbit the planet at the same altitude would be

A. T/4
B. T/2
C. T
D. 2T
E. 4T
F. None of the above

Q-23) A satellite orbits the earth in a circular orbit with a radius R. Which of the following statements is true?

A. If the satellite's orbital radius increases, its tangential speed decreases
B. If the satellite's orbital radius increases, its tangential speed increases
C. If the satellite's orbital radius increases, its angular speed increases
D. If the satellite's mass decreases, its tangential speed increases
E. If the satellite's mass decreases, its angular speed increases
F. None of the above

Q-24) A UPS driver lifts a 4 kg box from the ground applying an upward constant force of 42 N. The box was initially at rest. Find the total work done on the box after two seconds of applying the force.
A. 2.0 J
B. 4.0 J
C. 6.0 J
D. 8.0 J
E. 10 J
F. None of the above

Q-25) A 5.00 kg block is attached to a horizontal spring fixed to the wall with a spring constant of 500 N/m. Both, the spring and the block rest on the floor. The coefficient of kinetic friction between the surface and the block is 0.500. If the block is pushed a distance of 0.4 m from the equilibrium position of the spring, what will be the speed of the block when it returns to the equilibrium position of the spring?
A. $\sqrt{10}$ m/s
B. $\sqrt{12}$ m/s
C. $\sqrt{14}$ m/s
D. $\sqrt{16}$ m/s
E. $\sqrt{18}$ m/s
F. None of the above

Q-26) A lemon with mass m falls from a tree and drops straight to the ground from a height h. If non-conservative forces were acting on the lemon, its speed just before heating the ground would be v_0. If the speed of the lemon is half v_0, what is the work done by non-conservative forces?
A. $-mgh$
B. $-\frac{1}{\sqrt{2}}mgh$
C. $-\frac{1}{2}mgh$
D. $-\frac{3}{4}mgh$
E. $-\frac{1}{4}mgh$
F. None of the above

Q-27) An unstretched spring with a spring constant of 500 N/m hangs from the ceiling. A block is attached to the string and slowly moves the spring down. After the spring stretches 10 cm, the block stops moving. Find the work done by gravity on the block while it was moving.
A. 500 J
B. 250 J
C. 50 J
D. 25 J
E. 5 J
F. None of the above

Q-28) A 5 kg mass rests at the top of a 15 m high track. The track descends to a level section. On the level section, there is a 5.00 m long rough patch with a coefficient of kinetic friction of 0.400 everywhere else the track is frictionless. At the end of the track, after the rough patch, is a spring. The mass slides down, hits the spring, and returns. After traveling over the rough patch both ways, how high up the hill does the mass slide before stopping?

A. 10 m
B. 11 m
C. 12 m
D. 13 m
E. 14 m
F. None of the above

Q-29) A park ranger, driving at 10 m/s, suddenly sees a deer frozen in the headlights. The ranger immediately applied the brakes and slowed down until the car, which weighed 100,000 N, stopped completely before hitting the deer. If it took the car 200 meters to stop, what is the magnitude of total work the car did during braking?

A. -100 kJ
B. -1000 kJ
C. -10000 kJ
D. -500 kJ
E. -5000 kJ
F. None of the above

Q-30) If the momentum of a system is conserved, what must be true?

A. All forces acting on the system must be conservative.
B. There can only be two objects in the system.
C. The kinetic energy of the system is also conserved.
D. The objects that make up the system must be colliding.
E. The total momentum of the system is constant.
F. None of the above

Q-31) A particle with mass m_1 moves with a velocity v_0 toward a second particle of m_2 resting on a smooth horizontal table. They collide head-on in an elastic collision. After the collision, the speed of the first and second particles are v_1 and v_2. What is the kinetic energy of the system after the collision?

A. $\frac{1}{2}m_1v_1^2$
B. $\frac{1}{2}m_1v_2^2$
C. $\frac{1}{2}(m_1+m_2)v_1^2$
D. . $\frac{1}{2}(m_1+m_2)v_2^2$
E. . $\frac{1}{2}(m_1+m_2)v_0^2$
F. None of the above

Q-32) A batter hits a 0.5 kg baseball from rest with a force of 100 N. The ball is in contact with the bat for 10 ms. It is observed that the ball leaves the bat 1.6 m above the ground with an angle of 60 degrees with respect to the horizontal. What is the speed of the ball just before hitting the ground?

A. 2.0 m/s
B. 4.0 m/s
C. 6.0 m/s
D. 8.0 m/s
E. 10.0 m/s
F. None of the above

Q-33) A 0.100 kg golf ball is dropped from 4.00 m above the ground. After it bounces, it only reaches a height of 1.00 m above the ground. Find the magnitude of the impulse given to the ball when it bounces.

A. $\frac{\sqrt{2}}{10}$ kg m/s
B. $\frac{\sqrt{2}}{5}$ kg m/s
C. $\frac{\sqrt{2}}{2}$ kg m/s
D. $\frac{3}{\sqrt{2}}$ kg m/s
E. $\frac{3}{\sqrt{5}}$ kg m/s
F. None of the above

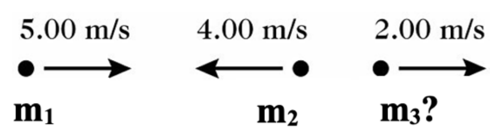
Q-34) A block with mass m is attached to a horizontal spring fixed to the wall with a spring constant k. Both, the spring and the block rest on the floor. A second block with mass m collides in a perfectly inelastic collision with the first one, with a speed v_0 compressing pushing the spring against the wall. Find the distance the spring is compressed.

A. $v_0\sqrt{\frac{m}{k}}$
B. $v_0\sqrt{\frac{m}{2k}}$
C. $v_0\sqrt{\frac{m}{4k}}$
D. $v_0\sqrt{\frac{2m}{k}}$
E. $v_0\sqrt{\frac{4m}{k}}$
F. None of the above

Time = sec

Q-35) Three objects are moving along a straight line, as shown in the figure; m_1=8 kg, m_2=9 kg. Taking the positive direction to be to the right, to keep the total momentum positive, what would the mass of the right object m^3 be?

A. $m_3 < 5$ kg
B. $m_3 < 10$ kg
C. $m_3 < 30$ kg
D. any m_3
E.Can not be determined from the information given.
F. None of the above



Q-36) A 90-kg runner makes a 90° turn. The speed before the turn is 3.00 m/s, and after the turn, it is 4.00 m/s. What is the magnitude of the change in the runner's momentum during the turn?

A. 90 kg m/s
B. 230 kg m/s
C. 340 kg m/s
D. 450 kg m/s
E. 630 kg m/s
F. None of the above

Q-37) A 3.00 kg mass suspended from a spring undergoes simple harmonic oscillations with a period of 2.00 s. How much mass must be added to the object to change the period to 6.00 s?
A. 6 kg
B. 9 kg
C. 12 kg
D. 24 kg
E. 30 kg
F. None of the above

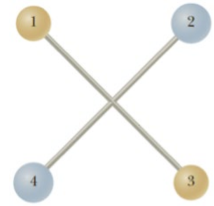
Q-38) A 3.00 kg mass attached to a horizontal spring undergoes simple harmonic oscillations. The associated angular frequency of the motion is 2.00 s^{-1}. If the total mechanical energy of the mass is 100 J, what is its Amplitude?
A. $\frac{10}{\sqrt{3}}$ m
B. $\frac{5}{\sqrt{2}}$ m
C. $\frac{2}{\sqrt{3}}$ m
D. $\frac{5}{\sqrt{3}}$ m
E. $\frac{10}{\sqrt{6}}$ m
F. None of the above

Q-39) The pendulum in a grandfather clock is designed to take 1.00 seconds to swing in each direction. If the maximum angle the pendulum rod can move from the vertical direction is 7.5 degrees, how much distance does the pendulum cover in one period of time?
A. $\frac{10}{\pi}$ m
B. $\frac{5}{\pi}$ m
C. $\frac{5}{2\pi}$ m
D. $\frac{5}{3\pi}$ m
E. $\frac{5}{6\pi}$ m
F. None of the above

Q-40) The pendulum in a grandfather clock is designed to take 1.00 seconds to swing in each direction. Find the pendulum's period if it is taken to a planet where the acceleration due to its gravity is 5 m/s^2
A. $\sqrt{8}$ s
B. $\sqrt{4}$ s
C. $\sqrt{2}$ s
D. $\frac{1}{\sqrt{2}}$ s
E. $\frac{1}{\sqrt{4}}$ s
F. None of the above

Q-41) A 25 kg mass attached to a spring undergoes simple harmonic oscillation described by x(t) = (10.0 m) cos(2.00 t). What is the maximum acceleration of this mass
A. 10 m/s^2
B. 20 m/s^2
C. 30 m/s^2
D. 40 m/s^2
E. 50 m/s^2
F. None of the above

Q-42) Consider a baton of four balls fastened to the ends of very light rods, as shown in the figure. Each rod is 1.00 m long, and the mass of each ball is 2.00 kg. Find the moment of inertia of the baton about an axis perpendicular to the page and passing through the middle of the rods where the rods cross.



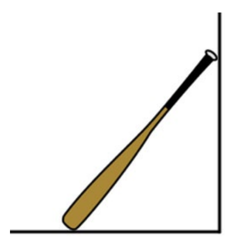
A. 1.00 kg m^2
B. 2.00 kg m^2
C. 4.00 kg m^2
D. 6.00 kg m^2
E. 8.00 kg m^2
F. None of the above

Q-43) A wheel with an inertia of 5.00 kg m^2 starts from rest and accelerates under a constant torque of 20.0 N m. What is the wheel's rotational kinetic energy after accelerating for 10.00 s?

A. 1000 J
B. 2000 J
C. 4000 J
D. 8000 J
E. 10000 J
F. None of the above

Q-44) A baseball bat with mass m leans against a vertical wall with the handle at the top, as shown in the figure. There is friction between the horizontal floor and the bat, but you may ignore friction at the wall. The bat has a length 3 m, and the center of mass of the bat is a distance 2 m from the handle end. When the bat is just on the verge of sliding, the angle between the bat and the floor is 60 degrees. What is the coefficient of static friction between the bat and the floor?

A. $3\sqrt{3}$
B. $\frac{1}{3\sqrt{3}}$
C. $\sqrt{3}$
D. $\frac{1}{3}$
E. 3
F. None of the above



Q-45) A yoyo consists of a light string wrapped around the outside of a solid cylinder, as shown in the figure. When released, the string unwraps, and the cylinder accelerates downward. Find the acceleration of the center of mass of the cylinder just after it is released. The cylinder has radius $R = 0.20$ m, mass $M = 0.15$ kg, and inertia $I = \frac{1}{4}MR^2$.

A. 2 m/s^2
B. 4 m/s^2
C. 6 m/s^2
D. 8 m/s^2
E. 10 m/s^2
F. None of the above

Q-46) A yoyo consists of a light string wrapped around the outside of a solid cylinder, as shown in the figure. When released, the string unwraps, and the cylinder accelerates downward. Find the speed of the cylinder after being realized from rest and has traveled a distance of 50 cm downward. The cylinder has radius $R = 0.20$ m, mass $M = 0.10$ kg, and inertia $I = \frac{1}{4}MR^2$.

A. $\sqrt{\frac{20}{3}}$ m/s
B. $\sqrt{\frac{4}{3}}$ m/s
C. $\sqrt{\frac{8}{5}}$ m/s
D. $\sqrt{5}$ m/s
E. $\sqrt{8}$ m/s
F. None of the above